NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

REPORT No. 381

STATIC, DROP, AND FLIGHT TESTS ON MUSSELMAN TYPE AIRWHEELS

By WILLIAM C. PECK and ALBERT P. BEARD

1931

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AERONAUTICAL SYMBOLS

1. FUNDAMENTAL AND DERIVED UNITS

	Symbol	Metric		English	
		Unit	Symbol	Unit	Symbol
Length	l	meter	m	foot (or mile)	ft. (or mi.)
Time	t	second	s	second (or hour)	sec. (or hr.)
Force	F	weight of one kilogram	kg	weight of one pound	lb.
Power	P	kg/m/s		horsepower	hp
Speed		km/h	k. p. h.	mi./hr.	m. p. h.
		m/s	m. p. s.	ft./sec.	f. p. s.

2. GENERAL SYMBOLS, ETC.

W, Weight $= mg$

g, Standard acceleration of gravity $= 9.80665$ m/s$^2 = 32.1740$ ft./sec.^{2}

m, Mass $= \frac{W}{g}$

ρ, Density (mass per unit volume).

Standard density of dry air, 0.12497 (kg-m^{-4} s^2) at 15° C. and 750 mm $= 0.002378$ (lb.-ft.$^{-4}$ sec.^{2}).

Specific weight of "standard" air, 1.2255 kg/m$^3 = 0.07651$ lb./ft.^{3}.

mk^2, Moment of inertia (indicate axis of the radius of gyration k, by proper subscript).

S, Area.

S_w, Wing area, etc.

G, Gap.

b, Span.

c, Chord.

$\frac{b^2}{S}$, Aspect ratio.

μ, Coefficient of viscosity.

3. AERODYNAMICAL SYMBOLS

V, True air speed.

q, Dynamic (or impact) pressure $= \frac{1}{2}\rho V^2$.

L, Lift, absolute coefficient $C_L = \frac{L}{qS}$

D, Drag, absolute coefficient $C_D = \frac{D}{qS}$

D_o, Profile drag, absolute coefficient $C_{D_o} = \frac{D_o}{qS}$

D_i, Induced drag, absolute coefficient $C_{D_i} = \frac{D_i}{qS}$

D_p, Parasite drag, absolute coefficient $C_{D_p} = \frac{D_p}{qS}$

C, Cross-wind force, absolute coefficient $C_C = \frac{C}{qS}$

R, Resultant force.

i_w, Angle of setting of wings (relative to thrust line).

i_t, Angle of stabilizer setting (relative to thrust line).

Q, Resultant moment.

Ω, Resultant angular velocity.

$\rho\frac{Vl}{\mu}$, Reynolds Number, where l is a linear dimension.

e. g., for a model airfoil 3 in. chord, 100 mi./hr. normal pressure, at 15° C., the corresponding number is 234,000;

or for a model of 10 cm chord 40 m/s, the corresponding number is 274,000.

C_p, Center of pressure coefficient (ratio of distance of $c. p.$ from leading edge to chord length).

α, Angle of attack.

ϵ, Angle of downwash.

α_o, Angle of attack, infinite aspect ratio.

α_i, Angle of attack, induced.

α_a, Angle of attack, absolute.
(Measured from zero lift position.)

γ, Flight path angle.

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By WILLIAM C. PECK and ALBERT P. BEARD
Langley Memorial Aeronautical Laboratory

36726—31——1

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

NAVY BUILDING, WASHINGTON, D. C.

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EXECUTIVE COMMITTEE

REPORT No. 381

STATIC, DROP, AND FLIGHT TESTS ON MUSSELMAN TYPE AIRWHEELS

By William C. Peck and Albert P. Beard

SUMMARY

This investigation was conducted at the Langley Memorial Aeronautical Laboratory of the National Advisory Committee for Aeronautics during the period from January to July, 1930, for the purpose of obtaining quantitative information on the shock-reducing and energy-dissipating qualities of a set of 30 by 13–6 Musselman type airwheels. The investigation consisted of static, drop, and flight tests. The static tests were made with inflation pressures of approximately 0, 5, 10, 15, 20, and 25 pounds per square inch and loadings up to 9,600 pounds. The drop tests were made with inflation pressures of approximately 5, 10, 15, 20, and 25 pounds per square inch and loadings of 1,840, 2,440, 3,050, and 3,585 pounds. The flight tests were made with a VE–7 *airplane weighing 2,153 pounds, with the tires inflated to 5, 10, and 15 pounds per square inch. The landing gears used in conjunction with the airwheels were practically rigid structures.*

The results of the tests showed that the walls of the tires carried a considerable portion of the load, each tire supporting a load of 600 pounds with a depression of approximately 6 inches.

The shock-reducing qualities, under severe tests, and the energy-dissipating characteristics of the tires, under all tests, were poor. The latter was evidenced by the rebound present in all landings made. In the severe drop tests, the free rebound reached as much as 60 per cent of the free drop.

The results indicate that a shock-reducing and energy-dissipating mechanism should be used in conjunction with airwheels.

INTRODUCTION

Recently a new type of wheel known as an "airwheel" has been developed for use on airplane landing gears. It consists of a low-pressure pneumatic tire of large sectional diameter mounted on a specially constructed hub. It has, in some cases, been used to replace the entire shock-absorbing and damping mechanism usually employed in landing gears.

The results of an investigation conducted at Wright Field on one of these wheels are given in Reference 1. The investigation reported herein was undertaken at the Langley Memorial Aeronautical Laboratory of the National Advisory Committee for Aeronautics at Langley Field, Va., to furnish further information on the action of these wheels under a variety of conditions. The investigation was made during the period from January to July, 1930, and consisted of a series of static, drop, and flight tests on a set of 30 by 13–6 Musselman type airwheels.

The static tests were made to determine the depression of the tires (decrease in rolling radius) under various loads with different inflation pressures. The drop tests were made to obtain information on the depression of the tires, the degree of rebound, and the maximum accelerations set up during the impacts in a series of free drops under various tire inflation pressures and loading conditions. The flight tests were made to determine the shock-reducing and energy-dissipating qualities of the wheels in actual landings under various tire inflation pressures.

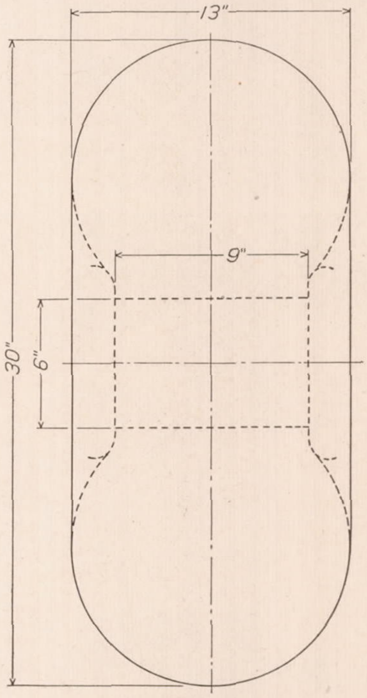

Figure 1.—30 by 13-6 Musselman type airwheel

APPARATUS

Equipment.—The airwheels used in this investigation were the 30 by 13–6, 8-ply, smooth-tread, Musselman type. (Fig. 1.) The sectional and rolling diameters shown are nominal, as they change slightly with a change in the inflation pressures.

For the static and drop tests, the airwheels were mounted on a modified NY–2 (consolidated training airplane) oleo landing-gear chassis (fig. 2), which in turn was mounted on the dynamic test rig (reference 2). A VE–7 (Vought) airplane weighing 2,153 pounds (with a modified landing gear) was used for the flight tests.

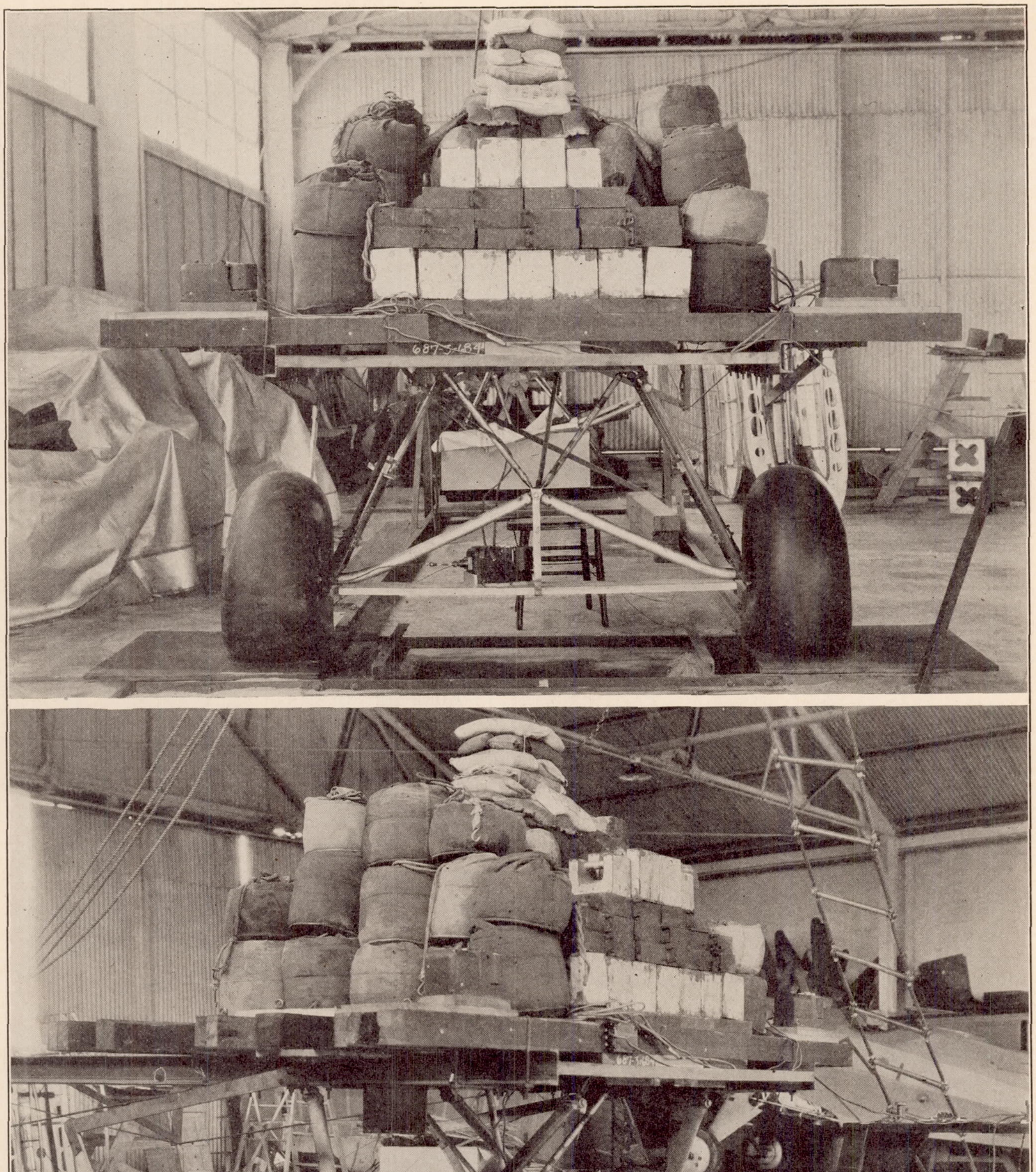

FIGURE 2.—Static test of airwheels on drop-test rig

The modification of the NY–2 landing-gear chassis consisted of replacing the rubber disks with a steel sleeve and blocking the oleo cylinder against this sleeve so that, with the exception of the flexure of the structural members of the landing gear, it was a rigid structure. (Fig. 3.) The normally moving parts of the VE–7 landing-gear chassis were also blocked so that for all practical purposes the only portions of the gear acting to reduce or absorb any of the impact loads were the airwheels. (Figs. 4 and 5.) (These pictures, showing the airwheels mounted on the VE–7 airplane, were taken after the landing gear had failed during a flight test. Normally the axles of the gear and the spreader bar were in the same straight line.)

The sectional diameter of the wheels necessitated a greater overhang of the axles than that for which the landing gears were designed, causing an increased bending moment in the axles for a given load. In these tests the NY–2 axles were not reinforced, with the exception of the use of adapters, while the VE–7 axles were reinforced throughout their length.

Instruments.—The instruments employed in this investigation consisted of a pressure recorder, a control-position recorder, an air-speed recorder, an anemometer, a spring-driven motion-picture camera, a recording accelerometer, and two timers.

The pressure recorder (fig. 3) was used during the static and drop tests to record the pressure in the right tire. This instrument was an air-speed recorder (reference 3) modified by replacing the usual manometer unit with one having a recording range from 0 to 50 pounds per square inch.

In the static and drop tests the control-position recorder (reference 4) was used in conjunction with a suitable reduction linkage to record the vertical displacement of the center of load, the depressions of the tires, and the flexure of the axles. In the flight tests, it was used in conjunction with a "follower arm" to record the approximate depression of the tires and the vertical displacement of the airplane while close to the ground. This follower arm was so constructed that the shoe at its lower extremity extended 16.7 inches below the line connecting the lower points of the tires, thereby allowing the shoe to make contact with the ground before the wheels. The shoe was held in contact with the ground by the use of heavy rubber cord.

One of the units of the control-position recorder was attached to the follower arm at such a point that movement of the arm throughout its complete range would cause a full-scale deflection of the instrument's recording mechanism.

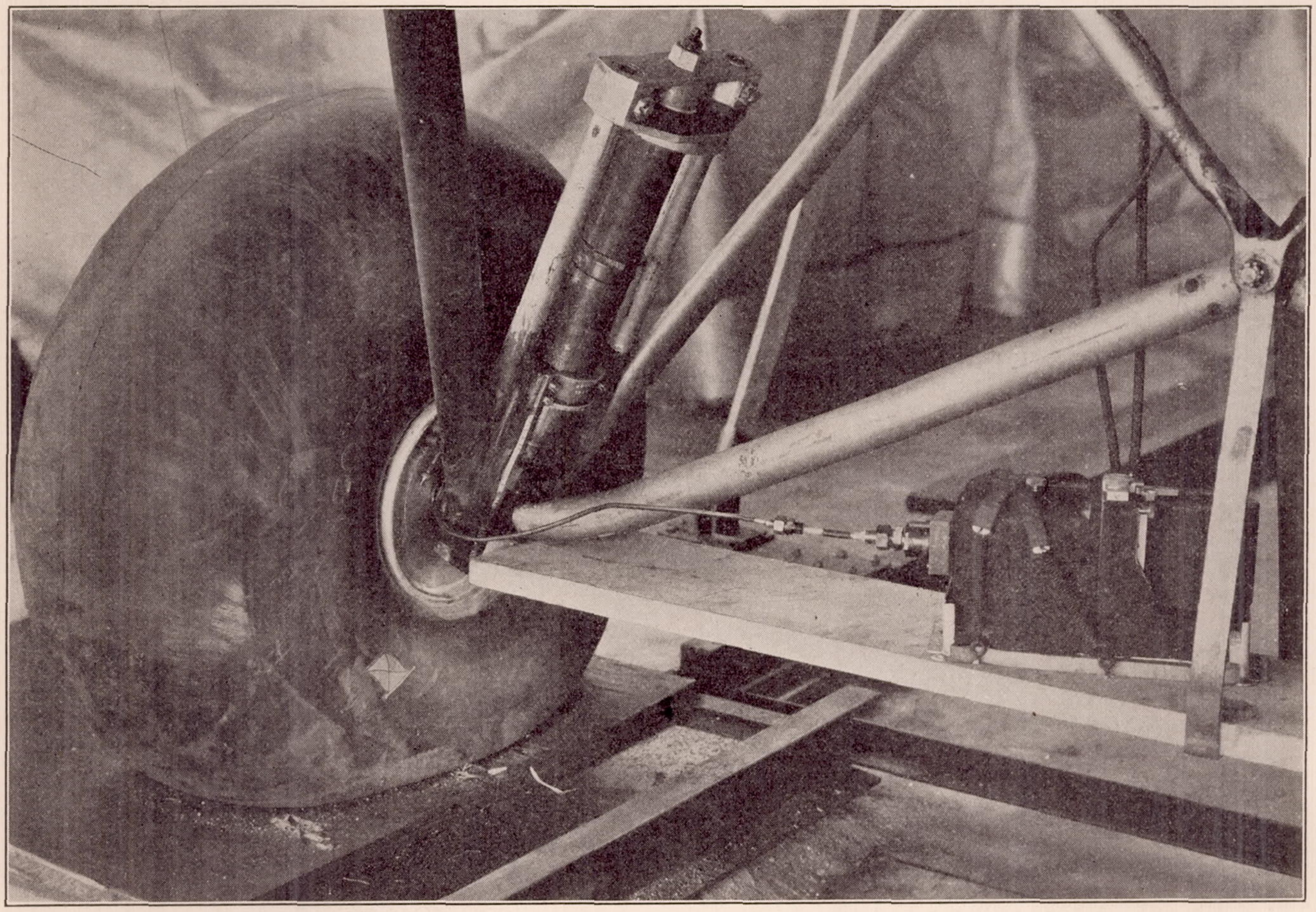

FIGURE 3.—Airwheel on modified NY–2 landing gear chassis showing tire-pressure recorder

The air-speed recorder (reference 3) was used in conjunction with an N. A. C. A. swiveling Pitot-static head to record the air speed of the airplane during the flight tests.

The anemometer employed was a vane-type instrument. It was used to determine the average wind velocity over a short period of time (usually 1 minute) immediately preceding and following each of the flight tests.

The motion-picture camera was used in the first portion of the flight tests in an effort to check the measurements made by the control-position recorder. Its use was found to be unsatisfactory, due to the impossibility of determining with a sufficient degree of accuracy the height of the airplane above the ground.

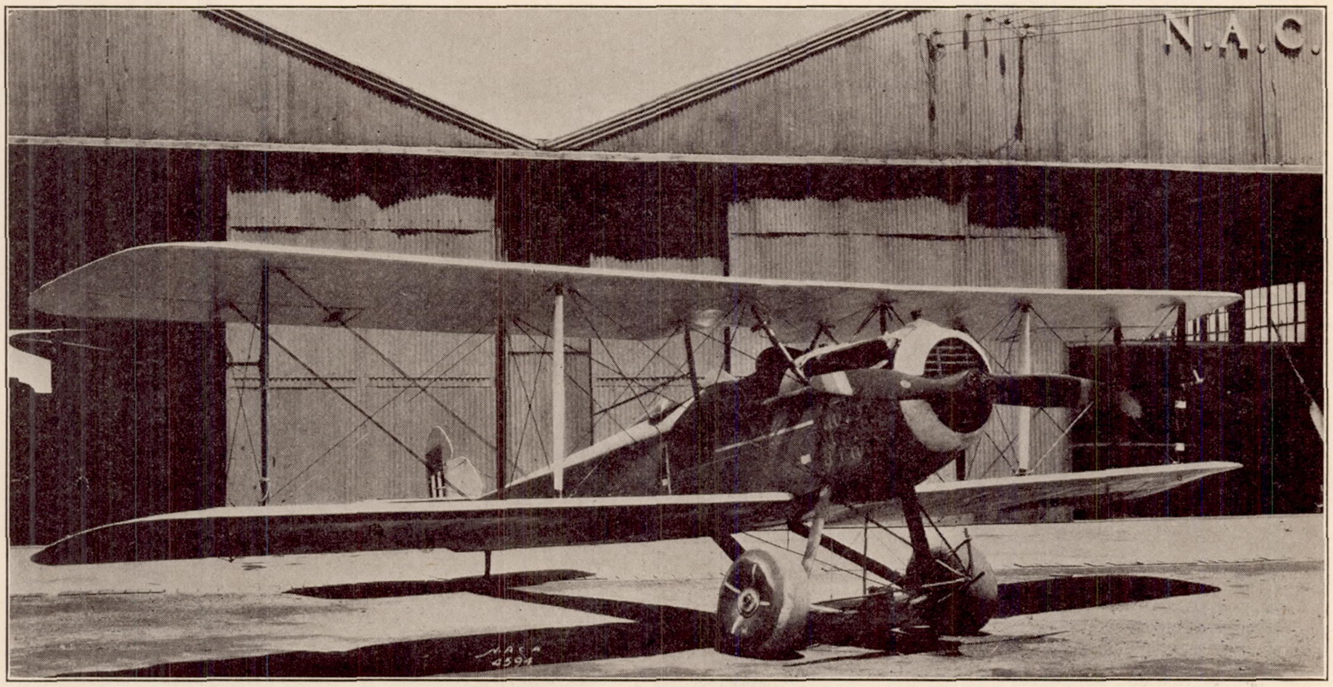

FIGURE 4.—Airwheels mounted on the VE-7 (Vought) airplane

The accelerometer (reference 5) was a single component type and was employed in both the drop and flight tests to record the vertical accelerations generated during the impacts. This instrument was adjusted to have a range from 0 to 8 g.

Two different types of timers were used during the investigation. One type was employed during the first portion of the drop tests and the second type during the latter portion of the flight tests. These instruments were used to synchronize the records obtained (reference 6) and also to obtain a history (if so desired) of the various measurements recorded.

The timer employed during the drop tests operated upon the principle of using the frequency of an alternating current to obtain uniform time intervals. It consisted of a half-wave rectifier connected to variable resistances and the timing lights of the instruments. The input side of the rectifier was connected to a 60-cycle, 110-volt source. The output side was connected in series with the variable resistances and the timing lights. The variable resistances were so adjusted that the filaments of the lights would vary from a dull red to full brilliancy with the pulsation of the current from the rectifier. The dull red did not register on the film record, while the filament at full brilliancy caused dots to be recorded at intervals of one-sixtieth second. The use of this instrument was but partially satisfactory, as a source of constant voltage and frequency which is necessary for its successful operation, was not available.

The timer used during the latter portion of the flight tests indicated time intervals of one-fifth second. It consisted of a commutator circuit breaker driven by a constant-speed motor.

Installation.—For the static and drop tests the air wheels were mounted on the NY-2 landing gear chassis, as shown in Figure 2. The center of the load box (with the tires merely touching the landing platforms) was vertically over the center line of the axles. With the test rig in this position, the longitudinal axis of the frame was practically horizontal.

The control-position recorder was mounted on the load platform adjacent to the load box. One unit of it was connected to the mechanical reduction linkage and a second unit to the center of the hub cap of the right wheel.

The pressure recorder was mounted on a platform suspended from the axles and connected by means of a short copper tube to the valve of the right tire. (Fig. 3.) The tube and recording capsule were, at the outset of the tests, filled with a 50-50 solution of alcohol and glycerin. It was found later that more

satisfactory results were obtained by dispensing with the use of the liquid.

The accelerometer was mounted alongside the load box on the load platform with its indicating mechanism in the same vertical plane as the center of the load and the center line of the axles.

The timer was mounted in a convenient position near the test rig and connected with the necessary leads to the instruments.

In the flight tests the airwheels were mounted on the VE-7 landing-gear chassis as close to the positions occupied by the regular wheels as their sectional diameter would permit. Normally, the center lines of the wheels were 4½ inches from the center lines of the side struts, while with the airwheels this distance was increased to 9 inches. The control-position recorder was mounted on the spreader bar of the landing-gear chassis. The follower arm was secured to the landing gear so that its shoe made contact with the ground in line with the points of contact of the wheels. The accelerometer was mounted in the airplane as close as practicable to the center of gravity. The air-speed recorder, timer, and necessary storage batteries were placed in a compartment aft of the pilot's cockpit. The swiveling Pitot-static head was mounted on the right outer interplane strut approximately one-third of the strut length below the upper wing.

The anemometer used to obtain the wind velocity was mounted on a vane about 6 feet above the ground on that portion of the field whereon the flight tests were being conducted.

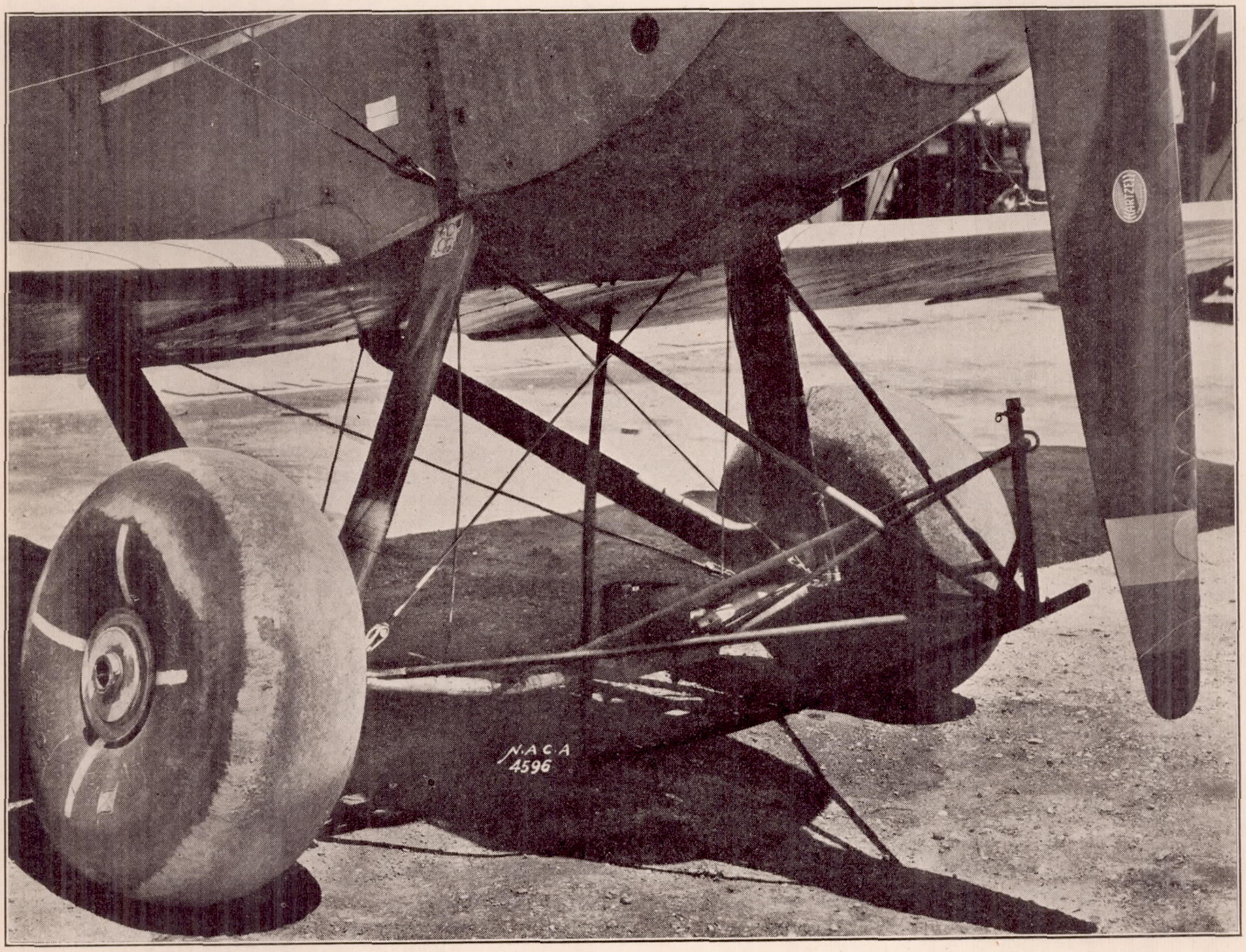

FIGURE 5.—"Follower arm" on landing gear chassis

PROCEDURE

Static tests.—Static tests were made with tire-inflation pressures of approximately 0, 5, 10, 15, 20, and 25 pounds per square inch. With each pressure the load on the test rig was applied in increments of approximately 800 pounds from no load to a load which depressed the tires nearly their maximum amount or until a load of 9,600 pounds had been reached. After each increase of load, the depression of the tires was measured and the pressure in them recorded.

Drop tests.—The drop tests consisted of a series of free drops with the tires inflated to each of the above pressures (with the exception of the zero pressure)

and with loadings of 1,840, 2,440, 3,050, and 3,585 pounds. Each series was made up of free drops starting at 1 inch and increasing in increments of 3 inches for the light loading conditions and in increments of 2 inches for the heavier loadings. The height of free drop was carried to a point at which the tires were depressed nearly their maximum allowable amount, or until the maximum force developed approached that for which the landing gear was designed. It was intended to discontinue the tests prior to actual failure of the landing gear, but on two occasions failure by bending of the axles resulted.

During each of the tests instrument records were taken of the total vertical movement of the center of the load, the rebound of this load, the flexure of the axle, the accelerations developed, and the pressures in the right tire.

Flight tests.—The flight tests consisted of landings and ground runs made with tire-inflation pressures of 5, 10, and 15 pounds per square inch. The tests consisted of normal, 2-point, pancake or "stalled" landings, and take-off and taxi runs. The normal and 2-point landings were made as nearly perfect as possible by experienced test pilots. The pancake landings were made as severely as deemed safe by these pilots. The taxi runs were made at a ground speed of approximately 15 m.p.h. In the take-off runs the airplane was "flown off" the ground rather than "pulled off." The portion of the landing field used in making these tests was representative of an average grass-covered landing field.

Continuous records of the accelerations experienced, the approximate depressions of the tires, and the rebounds were obtained; and the average wind velocity was measured for each of the flight tests. During some of these tests sufficient information was obtained from the recorded displacement obtained with the follower arm to determine the vertical velocity of the airplane at the instant of contact with the ground. This information was used in conjunction with the noted attitude of the airplane at contact to classify the type of landing made.

PRECISION

Static tests.—During the static tests the loads were noted to the nearest 10 pounds, the depressions were measured to the closest 0.01 inch, and the pressure records were read to 0.1 pound per square inch. A "dead-weight" calibration of the pressure recorder made subsequent to this portion of the investigation checked that made prior to it. Since the physical measurements were made with due care, the accuracy of the results of the static tests are therefore believed to be within the above limits.

Drop tests.—It is difficult to estimate the accuracy of the results obtained in the drop tests, but if it is assumed that the compression of the air in the tires during the static tests was isothermal and during the drop tests adiabatic, and that the change in volume in the tires for a given depression and inflation pressure was the same for the drop tests as for the static tests, an estimate can be made. By the use of these assumptions and the pressures recorded in the static tests, the maximum pressure in the drop tests can be computed. Several such computations were made and checked against the recorded drop-test pressures. The comparison indicated that the recorded pressures were slightly high. They were, however, within 5 per cent of the computed values.

The load displacement and acceleration histories (Figs. 15 and 16) indicate that there was a lag of approximately 0.025 second in the accelerometer records. This lag combined with the slight vibration in the recording and indicating mechanism may have caused the recorded accelerations to be somewhat in error. However, it is estimated that the accelerations recorded are not in error by more than ± 5 per cent.

The film records of the control position recorder could be read to the closest 0.01 inch. A displacement of the image on the film record of 0.01 inch corresponded to an approximate movement of the load of 0.20 inch. Therefore the error in the recorded vertical movement of the load and the tire depressions probably did not exceed 0.20 inch.

The unit of the control-position recorder used to record the flexure of the axle was so connected that a movement of the image on the film record of 0.01 inch corresponded to a flexure of the axle of approximately 0.10 inch. The flexures are probably within 0.10 inch of the true value.

Flight tests.—In the flight tests the accelerometer was subjected to test conditions which were very similar to those encountered in the drop tests, with the exception that the range of accelerations experienced was not so great. It can, therefore, be assumed that the accelerations recorded during this portion of the investigation are within the same limits of accuracy (± 5 per cent) as those taken in the drop tests.

Subsequent tests on the same VE–7 airplane indicated that the recorded air speeds at landing obtained in this investigation were in error by less than ± 4 per cent.

The average wind velocities, as measured by the anemometer, are considered to be within ± 3 m. p. h. of the true wind velocity at the instant of contact of the airplane with the ground during the tests.

A vertical movement of the airplane of approximately 0.15 inch (when the follower shoe was in contact with the ground) resulted in a displacement of the image on the control position-recorder record of 0.01 inch. Due to irregularities in the field the mechanism at times may have recorded erroneously the height of the airplane. These irregularities were, in a majority of cases, eliminated from the film records by fairing.

Considering the accuracy with which the films could be read and that attained by fairing the records, it is believed that the depressions of the tires and the bouncing of the airplane were determined within an accuracy of ±0.5 inch.

Since the vertical movement of the airplane was recorded during the 16.7 inches prior to the tires making contact with the ground and since the accuracy of the recording mechanism was estimated to be within ±0.5 inch, it can be assumed that the computed vertical velocity at contact is within ±3 per cent of the true value.

RESULTS

Static tests.—The results of the static tests are presented in curve form in Figure 6. This set of curves shows the interrelation between the static loads on the tires, the depressions of the tires, the inflation pressures, and the increases in tire pressures. Only two of the curves shown (0 and 25 pounds per square inch inflation pressure) were drawn through the experimental points obtained. The other curves were obtained from interpolation between the experimental points.

Drop tests.—Tables I to IV, inclusive, and Figures 7 to 14, inclusive, show the results of the drop tests in which loadings of 1,840, 2,440, 3,050, and 3,585 pounds, respectively, were used. The free drop noted is the vertical distance through which the center of load was given an unrestrained drop in making the test. The total drop is the vertical displacement of the center of load from the position occupied at the start of the free drop to the lowest position reached at the maximum depression of the tires. The total rebound is the vertical displacement of the center of the load from the maximum depression of the tires to the crest of the rebound. The free rebound is the vertical displacement of the load from the instant the tires leave the load platform, on the first bounce, to the crest of that bounce. The axle flexure is the vertical displacement of the load due to the bending of the axle. The maximum acceleration expressed in terms of g indicate the ratio between the maximum force on the tires developed during the initial contact of the wheels with the landing platforms and the static load on the tires. The maximum pressure in the tires is that recorded at the instant of maximum depression of the tires at the end of the initial stroke.

Figures 15 and 16, respectively, are histories of the displacement of the center of load and the accelerations for a 6-inch free drop of 3,585 pounds with an inflation pressure of 15 pounds per square inch.

Flight tests.—Tables V, VI, and VII are made up from the data obtained in the flight tests. The air speed, wind speed, vertical velocity, and ground speed are the values recorded or calculated for the instant of contact of the airplane with the ground. The first maximum acceleration noted is that developed in the initial stroke or tire depression, and the second is that developed in the subsequent ground run. The free rebound is the vertical distance that the wheels left the ground during the first bounce of the airplane.

Figures 17, 18, and 19 are motion-picture records of a normal, a 2-point, and a pancake or "stalled" landing, respectively. Each set of pictures is made from consecutive exposures taken during the tests with the camera operated at a rate of 32 exposures per second.

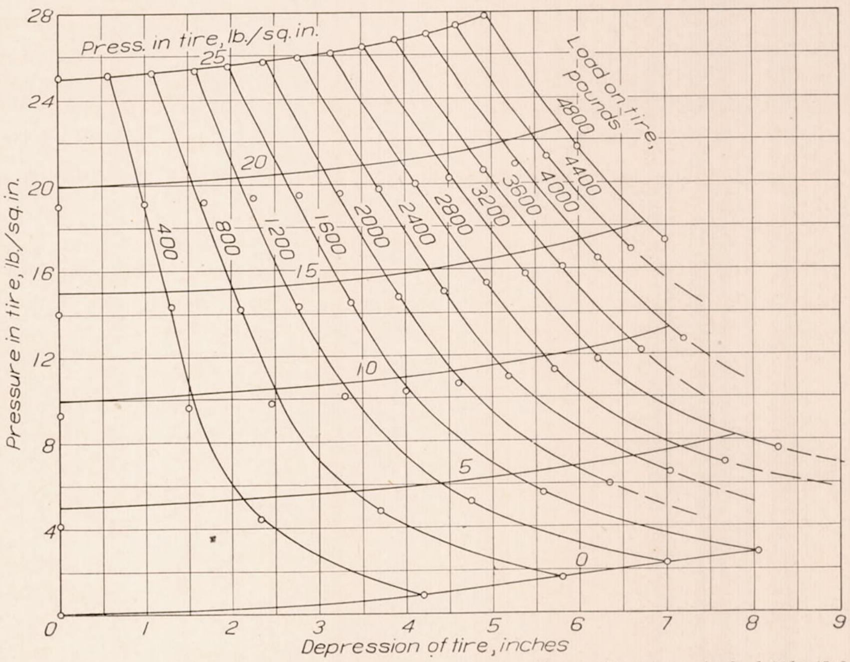

FIGURE 6.—Load-pressure-depression curves from static load calibration of a Musselman airwheel, 30 by 13–6

Figure 17, the normal landing, shows the airplane from slightly before it made contact with the ground until shortly after it reached the crest of the first bounce. Figure 18, the 2-point landing, starts immediately after the airplane had made initial contact. Figure 19 shows the pancake landing with the airplane being "stalled" onto the ground and the subsequent bounce.

DISCUSSION OF RESULTS

Static tests.—The series of tests with an inflation pressure of zero pounds showed that the stiffness of the tire walls had a pronounced influence on its load-carrying capacity. In this series each tire supported a load of 870 pounds with a depression of approximately 6 inches (see fig. 6) and developed an internal pressure of 1.8 pounds per square inch. With the valve cores removed so that no pressure could be developed, the tires supported a load of 600 pounds each with approximately the same depression.

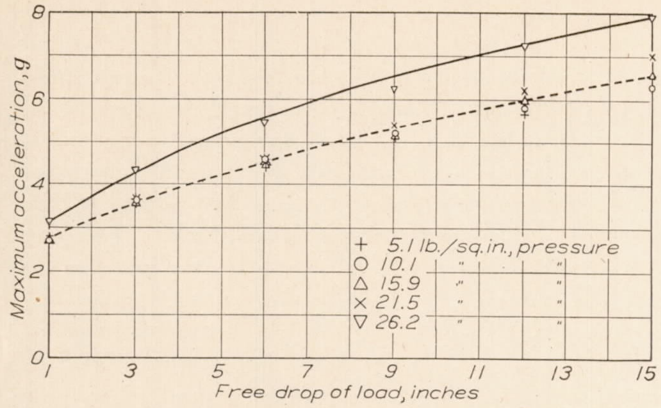

FIGURE 7.—Maximum accelerations vs. height of free drop; 1,840 pounds static loading

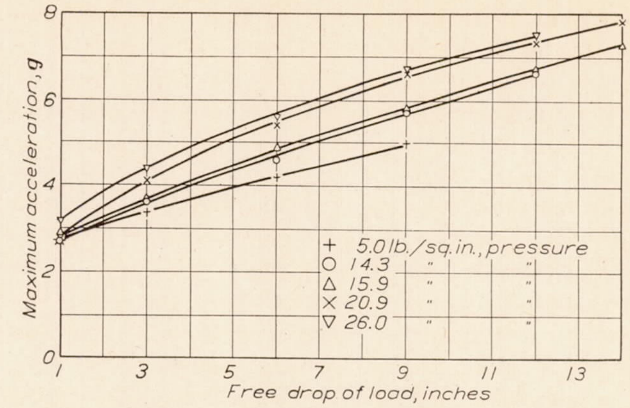

FIGURE 8.—Maximum accelerations vs. height of free drop; 2,440 pounds static loading

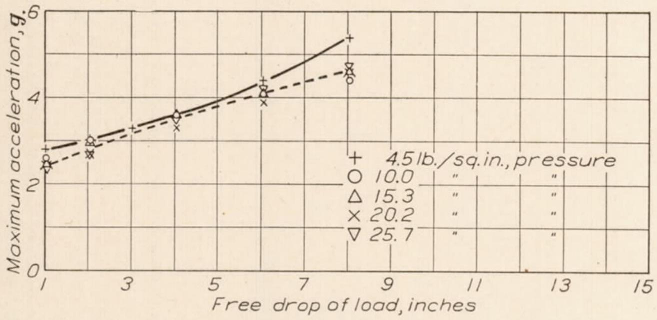

FIGURE 9.—Maximum accelerations vs. height of free drop; 3,050 pounds static loading

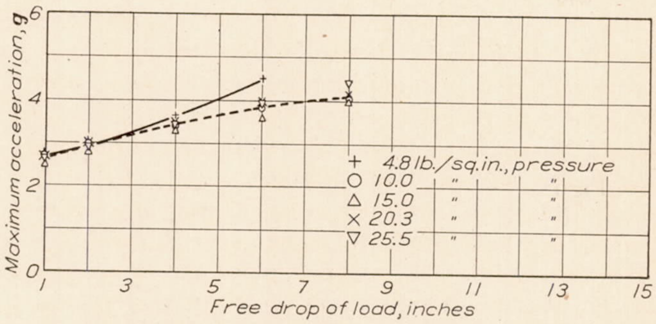

FIGURE 10.—Maximum accelerations vs. height of free drop; 3,585 pounds static loading

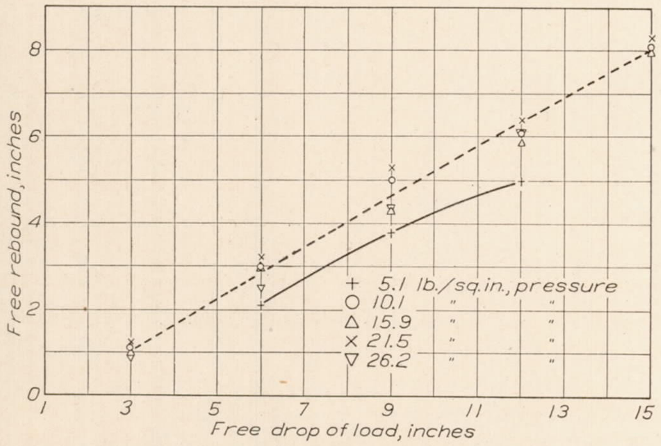

FIGURE 11.—Height of free rebound vs. height of free drop; 1,840 pounds static loading

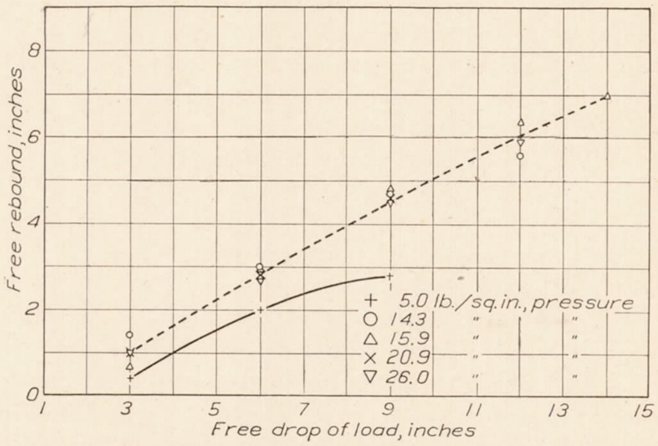

FIGURE 12.—Height of free rebound vs. height of free drop; 2,440 pounds static loading

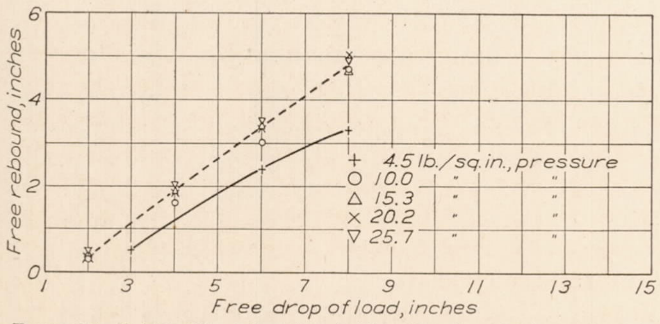

FIGURE 13.—Height of free rebound vs. height of free drop; 3,050 pounds static loading

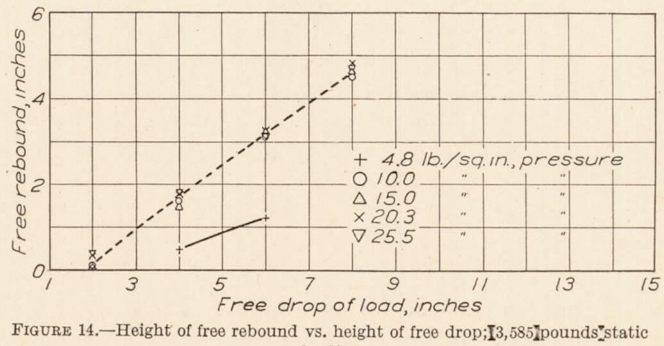

FIGURE 14.—Height of free rebound vs. height of free drop; 3,585 pounds static loading

The changes in pressure in the tires were small despite the large depressions realized. The increase in pressure, with a depression of 5 inches, varied from 1.1 to 2.9 pounds per square inch with inflation pressures of zero and 25 pounds per square inch, respectively. (Fig. 6.)

Drop tests.—The maximum accelerations developed in the drop tests are shown in Tables I to IV, inclusive, and Figures 7 to 10, inclusive. The figures show the variation of maximum accelerations with the height of free drop for various loads and inflation pressures. A comparison of these figures shows that the accelerations decrease to some extent with increased loadings. The effect of inflation pressures on the maximum accelerations depends to some extent on the load. For a static load of 1,840 pounds (fig. 7) the effect of changing the inflation pressure from 5.1 to 21.5 pounds per square inch was practically negligible, but a further increase to 26.2 pounds per square inch increased the maximum accelerations developed appreciably. With a loa of 2,440 pounds (fig. 8) the maximum accelerations show an appreciable and a more or less systematic increase with an increase in inflation pressure. For loads of 3,050 and 3,585 pounds (figs. 9 and 10) the effect of inflation pressure was negligible for pressures ranging from 10 to 25 pounds per square inch, but with the 5 pounds per square inch inflation pressure the maximum accelerations tend to increase rapidly when the height of free drop exceeds about 4 inches. It can therefore be

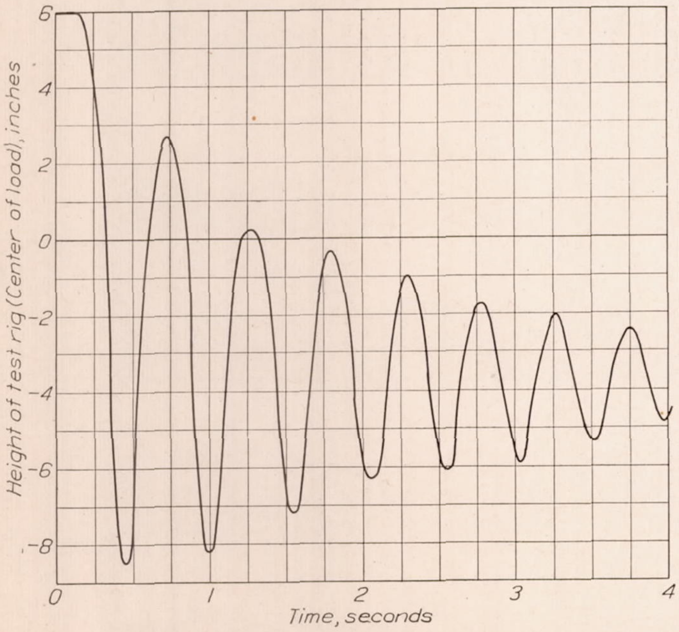

FIGURE 15.—Drop test history of test rig height of a 6-inch free drop with 3,585 pounds static load on tires and 15 pounds per square inch pressure

stated that, in general, for each loading there is a wide range in which the pressure changes have a small or negligible effect on the maximum accelerations.

The marked increase in maximum accelerations caused by increasing the inflation pressure to 26.2 pounds per square inch with the light load of 1,840 pounds and the decided increase in the slopes of the acceleration curves with the 5 pounds per square inch inflation pressure and loads of 3,050 and 3,585 pounds indicate that the useful range of the tires was some-

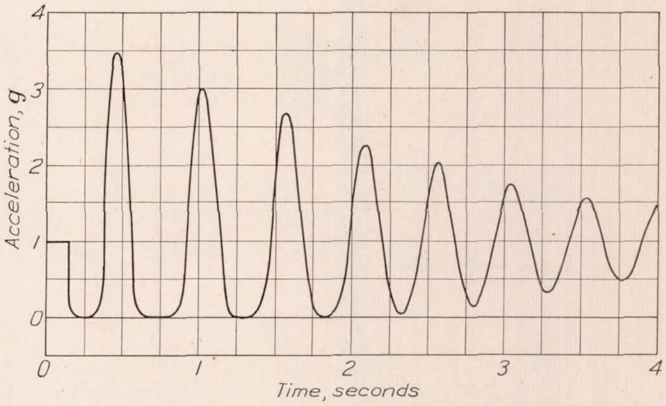

FIGURE 16.—Drop test history of acceleration from a 6-inch free drop with 3,585 pounds static load on tires and 15 pounds per square inch pressure

what limited by the ratio of the static load to the force required to obtain a given depression of the tires. With the light load and the high pressure, the force required to depress the tires was so large in comparison with the static load that the depression (corresponding to the stroke of the shock-absorbing units in a landing gear) was small. This resulted in the development of high maximum accelerations. With the heavier loadings and low inflation pressure the force required to depress the tires to their maximum was comparatively small with respect to the static loads. This resulted in the maximum depression being approached with relatively small free drops. In drops where the maximum depression was closely approached, a portion of the energy to be absorbed to bring the load to rest was taken by the more or less rigid structure of the landing gear. This caused a very rapid rise in the maximum accelerations.

The rate at which the maximum accelerations increased with height of free drop indicated that for free drops approaching those required by the Department of Commerce for landing gear tests (18 to 24 inches) the maximum accelerations would be excessive. This excessive impact load was partially the cause of two failures, by bending of the axles, that occurred during this investigation. The other major cause of the failures was the increase in overhang of the axles necessitated by the use of the airwheels. This increase in overhang was from 6⅝ inches for the wheels normally used to 8½ inches for the airwheels and resulted in an increase in bending moment of approximately 28 per cent for the same load.

However, this increase alone was not sufficient to be wholly responsible for the failures. The tests in which the failures occurred were with 15-inch free drops under a static load of 3,585 pounds. The same landing chassis had, in previous tests equipped with its normal shock-

FIGURE 17.—Normal landing

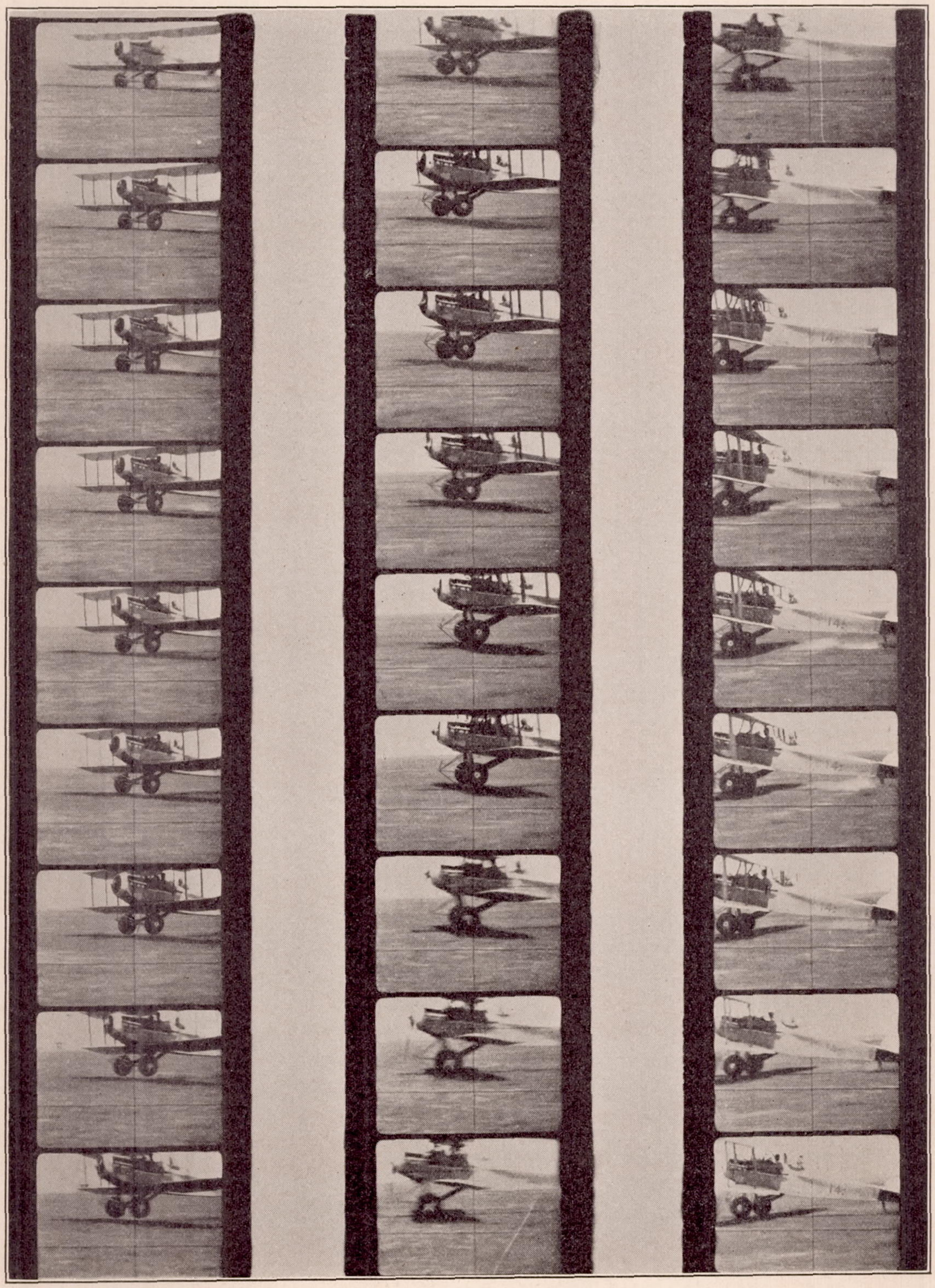

FIGURE 18.—Two-point landing

FIGURE 19.—Pancake landing

absorbing system, successfully withstood a free drop of 26 inches under the same static loading. This was an increase in height of free drop of 73 per cent. Thus, it can be stated that the decrease in shock-reducing characteristics experienced with the replacing of the normal shock-absorbing system by the airwheels greatly contributed to the cause of the failures.

Figures 11 to 14, inclusive, and Tables I to IV, inclusive, show the amount of rebound experienced by the load during the drop tests. It will be noted that in all the tests wherein the height of free drop exceeded 3 inches there was sufficient rebound to cause the tires to leave the landing platforms during the first bounce. The free rebound during the more severe tests varied from 50 to 60 per cent of the height of free drop. The excessive bouncing indicated that the airwheels are not efficient in the dissipation of energy.

It is interesting to note in the figures that under the inflation pressures of approximately 5 pounds per square inch there is a tendency for the height of free rebound to approach a constant value for each of the loadings. This tendency is more pronounced in the heavier loadings and indicates that the limiting depression of the tire was being approached.

In preparing the landing gears, which were available for use in this investigation, the moving parts were blocked so that there was no relative motion between them with the exception of distortion of the structural members. This made the gears representative rigid ones. During the drop tests, however, it was noted that there was considerable flexure of the axles. This flexure, which was bending of the axles around the points of support on the side struts of the landing chassis, was so large that at times it accounted for as much as 13 per cent of the total stroke of the landing gear. The flexure of the axles had the effect of decreasing the maximum accelerations developed and of slightly increasing the height of rebound. It is thought that unless a specially designed landing chassis were used with the airwheels, this axle flexure or distortion of the structural members of the gear would be encountered to a more or less degree. Therefore the results of these tests may be considered representative.

It will be noted in comparing the increase in pressure in the tires realized in the static tests with that recorded during the drop tests, for specific depressions and inflation pressures, that the latter was the greater. This was due to the fact that in the static tests the heat of compression had sufficient time to dissipate, while in the drop tests such was not the case. This was partially the cause of a greater force being required to depress the tires a given amount in the drop tests.

Flight tests.—The maximum accelerations developed during initial contact in the normal and 2-point landings varied from 1.1 to 2.7 *g*, the majority being less than 2 *g*. Those developed in the 2-point landings were generally larger than those experienced in the normal landings. Probably this was due to the greater speed at which the irregularities of the landing field were encountered. In the ground runs, succeeding the initial contact, the accelerations were slightly greater than at contact and were comparable to those developed in the drop tests for a 1-inch free drop. The vertical velocity of the airplane at the instant of contact, during some of these landings, varied from 1.3 to 4.0 feet per second with a corresponding variation of maximum accelerations from 1.1 to 2.1 *g*.

In the pancake or "stalled" landings, the maximum accelerations at contact varied from 2.4 to 4.3 *g*, which are comparable to those obtained in the drop tests with a 6-inch free drop. During a portion of these landings the vertical velocity at contact varied from 4.0 to 10.5 feet per second. It will be noted that in the majority of pancake landings the vertical velocity at contact did not exceed 6 feet per second. In the two landings in which the vertical velocities were 10.5 and 9.4 feet per second, failure of some portion of the airplane structure occurred. During the landing in which the vertical velocity of 10.5 feet per second was attained, one of the forward transverse cabane diagonal wires was broken. In the landing in which the vertical velocity of 9.4 feet per second was attained, a maximum acceleration of 4.3 *g* was experienced and the fittings securing the vertical load wires to the spreader bar of the landing gear chassis were sheared. The condition of the landing gear after this failure is shown in Figure 20. It is thought that this failure was due primarily to the increased load on the fittings caused by the greater overhang of the axles made necessary by the use of the airwheels. This overhang amounted to 9.0 inches, while with the gear as normally used the overhang was only 4.5 inches. Thus, for equal loads on the wheels the loads on the fittings were twice those that would normally be experienced.

There was an appreciable rebound or bouncing of the airplane following the initial contact with the ground in all types of landings. This is shown in Tables V to VII, inclusive, and Figures 17 to 19, inclusive. The figures are motion-picture records taken at a rate of 32 exposures per second, showing representative types of landings. These landings were made with an inflation pressure of 5 pounds per square inch. A normal landing is shown in Figure 17. The air speed and the ground speed of the airplane at the instant of contact during this landing were 49 and 42 m. p. h., respectively. The maximum acceleration experienced during the initial contact was 1.4 *g* and was accompanied by a tire depression of approximately 4.8 inches. It will be noted that the airplane approached the ground with very low vertical velocity and remained on the ground for a considerable period of time prior to making the first bounce. Figure 18 shows the airplane immediately

after it had made contact with the ground in a 2-point landing at air and ground speeds of 55 and 42 m. p. h., respectively. The maximum acceleration during the initial contact of this landing was 1.8 *g* with a tire depression of approximately 5.7 inches and a rebound of 14 inches. A fairly severe pancake landing is shown in Figure 19. It will be noted that during the initial contact the tires appear to have been depressed to nearly their maximum. The air speed and ground speed at contact in this landing were 48 and 38 m. p. h., respectively. The maximum acceleration developed was 4.1 *g* and the rebound exceeded the recording range of the follower arm (16.7 inches). The bounces experienced in the pancake landings were higher than those experienced in other types of landings. Those experienced in the 2-point landings were, in general, nearly equal to those experienced in the pancake landings and were much more violent and pronounced than those developed by the normal landings.

The maximum accelerations recorded during the drop tests indicated the maximum forces experienced on the wheels, while those recorded during the flight tests did not. This was due to the wheels being the sole means of supplying the restraining force to the load during the drop tests, and in the flight tests this restraining force was divided between the lift of the airplane and the force on the wheels. In some cases the lift of the airplane may have been nearly equal to the weight of the airplane. Thus, the maximum restraining force exerted by the wheels, in the flight tests, may have been as low as that indicated by the maximum accelerations less the weight of the airplane.

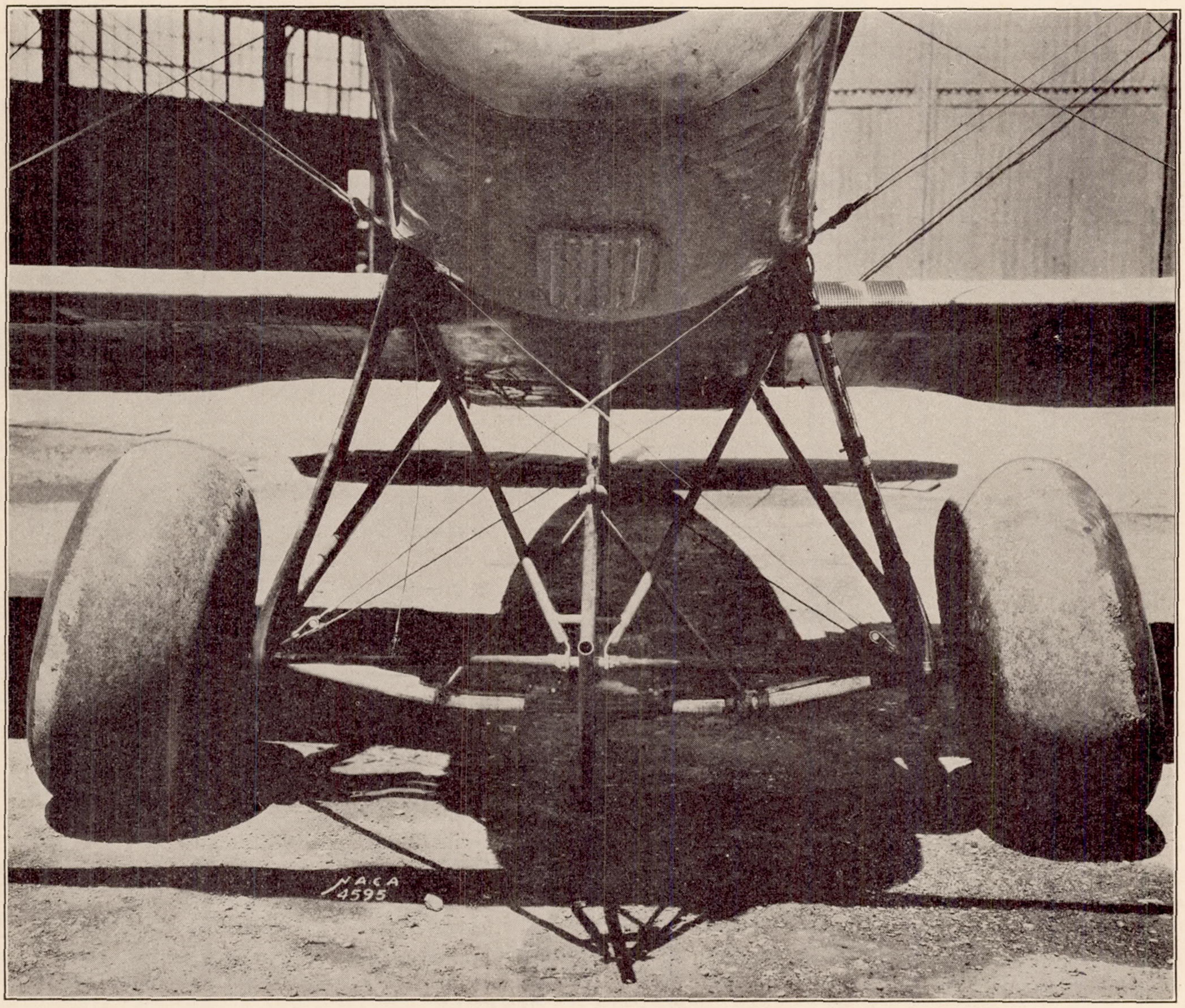

FIGURE 20.—Showing failure of VE-7 landing gear after severe pancake landing in tests of airwheels

Prior to making any tests on the airwheels it was found that their weight complete (less any braking mechanism) was approximately the same as the combined weight of the parts of the NY-2 chassis (i. e., wheels, tires, tubes, and oleo mechanism) that they were used to replace. However, with the adaption of

the airwheels to the NY–2 chassis, the ultimate strength of the chassis was lowered as a result of the increased overhang of the axles. If the ultimate strength of the chassis, after installation of the air wheels, had been brought up to the same ultimate strength as prior to the installation, heavier axles would have been required, with the result that the weight of the complete chassis would have been slightly greater. The increase in weight due to the heavier axles might be overcome by the use of a chassis especially designed for the airwheels instead of a modified one. However, it is believed that no appreciable amount of weight could be saved by the adoption of airwheels.

Attention is called to the fact that the relative advantages of the use of the airwheels on fields which are soft or otherwise adverse were not investigated during these tests. It is felt that due to the very large contact area of the airwheels and the low inflation pressures, their use on soft ground, on sand, or on a field covered with small stones would be advantageous. It is also believed that the tendency of the airwheels to cause excessive rebound and to develop high accelerations during severe impacts may be partially counteracted by the use of a shock-absorbing mechanism. Such a resulting system may incorporate the advantages of the airwheels with the advantages of other mechanisms in keeping down the impact loads and in dissipating a large portion of the energy taken by it.

CONCLUSIONS

1. The shock-reducing qualities of the airwheels were very poor under severe landing conditions.
2. The lack of ability of the airwheels to dissipate energy was very pronounced, as was evidenced by excessive rebounds.
3. Variations of the inflation pressure, within fairly wide limits which depend to some extent on the load, had but slight effect on the maximum accelerations and rebound.
4. The strength or "stiffness" of the walls of the tires accounted for an appreciable portion of the load-carrying capacity of the tires.
5. A shock-reducing mechanism capable of effectively reducing the impact forces in severe landings should be used in conjunction with the airwheels.
6. It appears that no appreciable amount of weight would be saved by the use of airwheels.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics, Langley Field, Va., *October 8, 1930.*

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TABLE I

RESULTS OF DROP TESTS ON 30 BY 13–6 AIRWHEELS

Loading (on both wheels) 1,840 pounds

TIRE INFLATION PRESSURE 5.1 POUNDS PER SQUARE INCH

Free drop (in.)	Total drop (in.)	Free rebound (in.)	Total rebound (in.)	Tire depression (in.)	Axle flexure ℄ tire (in.)	Maximum acceleration (g)	Maximum tire pressure (lb./sq. in.)
1.0	7.3	----------	5.2	6.0	0.30	2.8	7.0
3.0	9.7	0.2	6.9	6.3	.45	3.6	7.3
6.0	13.4	2.1	9.4	6.8	.60	4.4	8.4
9.0	17.2	3.8	12.0	7.6	.65	5.1	8.7
12.0	21.6	5.0	14.6	8.9	.75	5.7	9.3

TIRE INFLATION PRESSURE 10.1 POUNDS PER SQUARE INCH

Free drop (in.)	Total drop (in.)	Free rebound (in.)	Total rebound (in.)	Tire depression (in.)	Axle flexure ℄ tire (in.)	Maximum acceleration (g)	Maximum tire pressure (lb./sq. in.)
1.0	5.9	----------	4.5	4.6	0.35	2.7	12.0
3.0	8.4	1.1	6.4	5.0	.45	3.6	12.9
6.0	12.3	3.0	9.3	5.7	.55	4.6	13.7
9.0	15.6	5.0	11.6	6.1	--------	5.2	15.1
12.0	18.7	6.1	12.9	----------	.65	5.8	15.6
15.0	22.8	8.1	15.9	7.0	.85	6.3	16.5

TIRE INFLATION PRESSURE 15.9 POUNDS PER SQUARE INCH

Free drop (in.)	Total drop (in.)	Free rebound (in.)	Total rebound (in.)	Tire depression (in.)	Axle flexure ℄ tire (in.)	Maximum acceleration (g)	Maximum tire pressure (lb./sq. in.)
1.0	5.1	----------	4.0	3.8	0.35	2.7	17.1
3.0	8.1	1.0	6.1	4.6	.45	3.7	18.0
6.0	12.0	3.0	9.0	5.5	.55	4.5	18.8
9.0	15.0	4.3	10.3	------	.60	5.2	19.5
12.0	19.6	5.9	13.5	6.8	.75	6.0	20.9
15.0	22.8	8.0	15.7	7.0	.80	6.6	21.7

TIRE INFLATION PRESSURE 21.5 POUNDS PER SQUARE INCH

Free drop (in.)	Total drop (in.)	Free rebound (in.)	Total rebound (in.)	Tire depression (in.)	Axle flexure ℄ tire (in.)	Maximum acceleration (g)	Maximum tire pressure (lb./sq. in.)
3.0	7.6	1.2	5.8	4.0	----------	3.6	23.7
6.0	11.8	3.2	9.0	5.2	0.60	4.5	24.5
9.0	14.8	5.3	10.1	----------	.65	5.4	24.8
12.0	18.5	6.4	12.9	5.8	.70	6.2	25.3
15.0	22.5	8.3	15.8	6.8	.75	7.0	25.6

TIRE INFLATION PRESSURE 26.2 POUNDS PER SQUARE INCH

Free drop (in.)	Total drop (in.)	Free rebound (in.)	Total rebound (in.)	Tire depression (in.)	Axle flexure ℄ tire (in.)	Maximum acceleration (g)	Maximum tire pressure (lb./sq. in.)
1.0	4.0	----------	2.8	2.7	0.35	3.1	27.3
3.0	7.3	0.9	5.2	3.8	.45	4.3	27.9
6.0	11.1	2.5	7.6	4.6	.50	5.5	28.7
9.0	15.1	4.3	10.3	5.4	.70	6.2	29.0
12.0	17.8	6.1	11.9	----------	.80	7.2	30.1
15.0	21.7	----------	----------	6.0	.75	7.9	30.7

TABLE II

RESULTS OF DROP TESTS ON 30 BY 13–6 AIRWHEELS

Loading (on both wheels) 2,440 pounds

TIRE INFLATION PRESSURE 5 POUNDS PER SQUARE INCH

Free drop (in.)	Total drop (in.)	Free rebound (in.)	Total rebound (in.)	Tire depression (in.)	Axle flexure ℄ tire (in.)	Maximum acceleration (g.)	Maximum tire pressure (lb./sq. in.)
1.0	8.0	----------	6.1	6.5	0.50	2.9	7.8
3.0	10.5	0.4	7.9	6.8	.61	3.4	8.7
6.0	14.5	2.0	10.5	7.7	.75	4.2	10.1
9.0	19.0	2.7	11.7	8.1	.94	5.0	11.2

TIRE INFLATION PRESSURE 14.3 POUNDS PER SQUARE INCH

Free drop (in.)	Total drop (in.)	Free rebound (in.)	Total rebound (in.)	Tire depression (in.)	Axle flexure ℄ tire (in.)	Maximum acceleration (g.)	Maximum tire pressure (lb./sq. in.)
1.0	6.4	----------	5.4	5.0	0.44	2.7	16.7
3.0	8.8	1.4	7.3	5.3	.57	3.6	17.4
6.0	12.3	3.0	9.3	5.5	.75	4.7	18.4
9.0	15.9	4.7	11.6	6.1	.86	5.7	19.7
12.0	20.4	5.6	14.0	7.4	1.03	6.6	20.9

TIRE INFLATION PRESSURE 15.9 POUNDS PER SQUARE INCH

Free drop (in.)	Total drop (in.)	Free rebound (in.)	Total rebound (in.)	Tire depression (in.)	Axle flexure ℄ tire (in.)	Maximum acceleration (g.)	Maximum tire pressure (lb./sq. in.)
1.0	6.0	----------	5.0	4.5	0.55	2.9	17.2
3.0	8.7	0.7	6.5	4.8	.64	3.7	18.5
6.0	12.1	3.0	9.1	5.3	.84	4.9	19.8
9.0	16.2	4.8	12.0	6.3	.95	5.8	20.9
12.0	19.6	6.4	14.0	6.6	1.01	6.7	21.7
14.0	22.3	7.0	15.3	7.1	1.07	7.3	22.6

TIRE INFLATION PRESSURE 20.9 POUNDS PER SQUARE INCH

Free drop (in.)	Total drop (in.)	Free rebound (in.)	Total rebound (in.)	Tire depression (in.)	Axle flexure ℄ tire (in.)	Maximum acceleration (g.)	Maximum tire pressure (lb./sq. in.)
1.0	5.3	----------	4.3	3.7	0.54	2.8	22.6
3.0	8.0	1.0	6.0	4.3	.73	4.1	23.7
6.0	11.9	2.8	8.7	5.1	.79	5.4	24.7
9.0	15.6	4.6	11.2	5.7	.95	6.6	25.7
12.0	----------	----------	----------	----------	----------	7.3	26.4
14.0	----------	----------	----------	----------	----------	7.8	27.0

TIRE INFLATION PRESSURE 26 POUNDS PER SQUARE INCH

Free drop (in.)	Total drop (in.)	Free rebound (in.)	Total rebound (in.)	Tire depression (in.)	Axle flexure ℄ tire (in.)	Maximum acceleration (g.)	Maximum tire pressure (lb./sq. in.)
1.0	4.7	----------	3.7	3.2	0.56	3.2	27.5
3.0	7.7	1.0	5.7	4.0	.69	4.4	28.4
6.0	12.2	2.7	9.0	5.4	.85	5.6	29.2
9.0	15.7	4.5	11.2	5.8	.94	6.7	30.0
12.0	19.5	5.9	13.4	6.4	1.06	7.5	31.5

TABLE III

RESULTS OF DROP TESTS ON 30 BY 13–6 AIRWHEELS

Loading (on both wheels) 3,050 pounds

Free drop (in.)	Total drop (in.)	Free rebound (in.)	Total rebound (in.)	Tire depression (in.)	Axle flexur ℄ tire (in.)	Maximum acceleration (g)	Maximum tire pressure (lb./sq. in.)
TIRE INFLATION PRESSURE 4.5 POUNDS PER SQUARE INCH							
1.0	9.8	----------	8.2	8.1	0.75	2.8	10.6
3.0	12.4	0.5	9.9	8.6	.82	3.3	12.1
6.0	16.3	2.4	12.7	9.2	1.04	4.4	13.6
8.0	18.6	3.3	13.9	9.4	1.20	5.4	14.0
TIRE INFLATION PRESSURE 10.0 POUNDS PER SQUARE INCH							
1.0	7.8	----------	6.5	6.0	0.72	2.6	14.2
2.0	9.2	0.3	7.5	6.5	.78	3.0	14.8
4.0	12.3	1.6	9.9	7.4	.89	3.6	16.3
6.0	15.3	3.0	12.3	8.2	1.02	4.1	17.9
8.0	17.5	4.7	14.3	8.5	1.06	4.4	18.5
TIRE INFLATION PRESSURE 15.3 POUNDS PER SQUARE INCH							
1.0	6.8	----------	5.4	5.1	0.65	2.5	18.4
2.0	8.5	0.4	6.9	5.8	.74	3.0	19.2
4.0	11.0	1.9	8.9	6.1	.85	3.6	20.2
6.0	13.8	3.4	11.1	6.8	.98	4.1	21.4
8.0	16.5	4.7	13.2	7.5	1.04	4.7	22.3
TIRE INFLATION PRESSURE 20.2 POUNDS PER SQUARE INCH							
1.0	----------	----------	----------	----------	----------	2.4	----------
2.0	7.6	0.3	5.9	4.9	0.69	2.7	23.3
4.0	10.4	1.8	8.3	5.6	.87	3.3	24.3
6.0	12.9	3.3	10.2	6.1	----------	3.9	25.2
8.0	15.6	5.0	12.5	6.5	1.02	4.5	26.1
TIRE INFLATION PRESSURE 25.7 POUNDS PER SQUARE INCH							
1.0	5.4	----------	4.3	3.8	0.61	2.4	27.2
2.0	6.8	0.5	5.3	4.1	.67	2.7	27.9
4.0	9.8	2.0	7.8	4.9	.83	3.5	29.0
6.0	12.5	3.5	10.0	5.6	.92	4.2	30.2
8.0	15.0	4.9	11.9	5.9	1.06	4.6	31.0

TABLE IV

RESULTS OF DROP TESTS ON 30 BY 13–6 AIRWHEELS

Loading (on both wheels) 3,585 pounds

Free drop (in.)	Total drcp (in.)	Free rebound (in.)	Total rebound (in.)	Tire depression (in.)	Axle flexure ℄ tire (in.)	Maximum acceleration (g)	Maximum tire pressure (lb./sq. in.)
TIRE INFLATION PRESSURE 4.8 POUNDS PER SQUARE INCH							
1.0	10.4	----------	8.7	8.5	0.92	2.7	12.4
2.0	11.7	----------	9.4	8.8	.91	2.9	13.1
4.0	14.0	0.5	10.4	8.9	1.06	3.6	14.2
6.0	16.5	1.2	11.7	9.2	1.26	4.5	14.2
TIRE INFLATION PRESSURE 10.0 POUNDS PER SQUARE INCH							
1.0	8.8	----------	7.3	7.0	0.83	2.7	15.5
2.0	10.4	0.1	8.5	7.5	.89	3.0	16.2
4.0	13.2	1.6	10.8	8.2	1.01	3.4	17.8
6.0	15.9	3.1	13.1	8.8	1.12	3.8	19.1
8.0	18.2	4.5	14.7	8.9	1.30	4.0	20.3
TIRE INFLATION PRESSURE 15.0 POUNDS PER SQUARE INCH							
1.0	7.9	----------	6.5	6.0	0.86	2.5	19.5
2.0	9.4	0.1	7.5	6.6	----------	2.8	19.8
4.0	12.1	1.5	9.6	7.2	.95	3.3	21.1
6.0	15.0	3.2	12.2	8.0	1.03	3.6	22.3
8.0	17.5	4.7	14.3	8.4	1.14	4.0	23.7
TIRE INFLATION PRESSURE 20.3 POUNDS PER SQUARE INCH							
1.0	6.8	----------	5.6	5.0	0.85	2.6	23.7
2.0	8.2	0.3	6.5	5.4	.82	3.0	24.3
4.0	11.2	1.7	8.9	6.2	.94	3.5	25.3
6.0	13.8	3.2	11.0	6.8	1.03	3.9	26.6
8.0	16.7	4.8	13.5	7.6	1.11	4.1	27.5
TIRE INFLATION PRESSURE 25.5 POUNDS PER SQUARE INCH							
1.0	6.2	----------	5.0	4.4	0.80	2.6	28.3
2.0	7.8	0.4	6.1	4.9	.86	2.9	28.8
4.0	10.7	1.8	8.5	5.8	.93	3.4	29.9
6.0	13.0	3.1	10.1	6.0	1.01	3.9	30.7
8.0	16.1	4.7	12.9	7.0	1.14	4.4	31.9

TABLE V

RESULTS OF FLIGHT TESTS ON 30 BY 13–6 AIRWHEELS

Mounted on VE–7 airplane, weight 2,153 pounds

TIRE INFLATION PRESSURE 5 POUNDS PER SQUARE INCH

Type of landing	Initial contact with ground							Run following contact	
	Air speed (m. p. h.)	Wind speed (m. p. h.)	Ground speed (m. p. h.)	Vertical velocity (ft./sec.)	Maximum (first) acceleration (g)	Tire depression (in.)	Free rebound (in.)	Maximum (second) acceleration (g)	Remarks
Normal	51	8	43		1. 5	5. 0	2. 7	1. 5	Smooth landing.
Do	52	4	48		1. 2	3. 4	3. 3	1. 5	Very good landing.
Do	50	4	46		1. 4	3. 8	6. 1	1. 9	
2-point	53	9	44		2. 7	7. 5	9. 0	2. 1	
Do	54	9	45		1. 9	4. 7	13. 2	2. 3	
Do	55	13	42		1. 8	5. 7	13. 9		
Pancake	50	9	41	4. 0	2. 6	6. 0		2. 5	Rebound greater than 16.7 inches. Rough landing.
Do	48	9	39	5. 1	3. 1	8. 3		2. 7	Rebound greater than 16.7 inches. Representative pancake; 10-foot drop.
Do	49	9	40	5. 6	2. 4	5. 3	14. 8	2. 3	Representative pancake not too severe; 12-foot drop.
Do	50	15	35	10. 5	3. 2	6. 8		2. 5	Very severe pancake.
Takeoff	49				1. 8	5. 8	3. 8		
	50	7	43			6. 3	5. 4		Very smooth take-off.
	53				1. 5	5. 0	3. 0		
Taxi					1. 7	5. 7	0. 00		Maximum values only.
					1. 8	6. 4	3. 00		Slightly cross wind.

TABLE VI

RESULTS OF FLIGHT TESTS ON 30 BY 13–6 AIRWHEELS

Mounted on VE–7 airplane, weight 2,153 pounds

TIRE INFLATION PRESSURE 10 POUNDS PER SQUARE INCH

Type of landing	Initial contact with ground							Run following contact	
	Air speed (m. p. h.)	Wind speed (m. p. h.)	Ground speed (m. p. h.)	Vertical velocity (ft./sec.)	Maximum (first) acceleration (g)	Tire depression (in.)	Free rebound (in.)	Maximum (second) acceleration (g)	Remarks
Normal	51	7	44	3. 5	1. 2	1. 5	5. 5	1. 8	Very smooth 3-point.
Do	49	10	39	2. 1	1. 1	4. 0	4. 7	2. 1	Excellent 3-point.
Do	49	5	44		1. 2	1. 5	7. 1	1. 6	Exceptioanally good 3-point landing.
2-point	57	13	44		1. 8	6. 5	15. 4	2. 3	Second bounce exceeded 16.7 inches.
Do	52	12	40		2. 5	6. 0		2. 7	Rebound greater than 16.7 inches.
Do		9		1. 3	2. 0	1. 0	9. 4	2. 0	Excellent landing.
Pancake	46	5	41		2. 9	3. 9	7. 2	2. 1	Rough 3-point landing.
Do		7		5. 1	2. 5	6. 1	9. 3	2. 0	Good example of pancake.
Do	46	7	39		2. 5	4. 3	6. 4	2. 2	Dropped in from approximately 5 feet.
Take-off	60	7	53		2. 5	7. 7	7. 3		Smooth take-off.
	57	9	48		2. 0	4. 0	5. 2		
Taxi					2. 1	3. 6	3. 6		Approximately 15 miles per hour ground speed.

TABLE VII

RESULTS OF FLIGHT TESTS ON 30 BY 13–6 AIRWHEELS

Mounted on VE–7 airplane, weight 2,153 pounds

TIRE INFLATION PRESSURE 15 POUNDS PER SQUARE INCH

Type of landing	Initial contact with ground							Run following contact	
	Air speed (m. p. h.)	Wind speed (m. p. h.)	Ground speed (m. p. h.)	Vertical velocity (ft./sec.)	Maximum (first) acceleration (g)	Tire depression (in.)	Free rebound (in.)	Maximum (second) acceleration (g)	Remarks
Normal	54				1. 1	2. 5	5. 0	1. 6	Slightly tail first.
Do	51	10	41		1. 3	2. 3	10. 1	1. 8	Good 3-point, field firm.
Do	50	8	42		1. 2			1. 8	Very good 3-point.
2-point	62				1. 1			2. 3	Good landing.
Do	58	9	49	3. 2	1. 5	4. 6	4. 9	2. 0	Very smooth landing.
Do	57	8	49	4. 0	2. 1	1. 5	12. 7	3. 9	Second bounce in excess of 16.7 inches.
Pancake	42	9	33	4. 2	2. 8	5. 8	11. 4	2. 4	Dropped in approximately 5 feet.
Do	45	8	37	9. 4	4. 3				Dropped in approximately 8 feet. Vertical load wire fittings on landing chassis parted.

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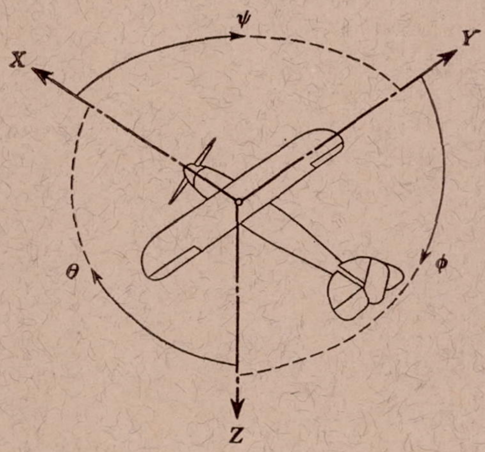

Positive directions of axes and angles (forces and moments) are shown by arrows

Axis		Force (parallel to axis) symbol	Moment about axis			Angle		Velocities	
Designation	Symbol		Designation	Symbol	Positive direction	Designation	Symbol	Linear (component along axis)	Angular
Longitudinal	X	X	rolling	L	$Y \longrightarrow Z$	roll	ϕ	u	p
Lateral	Y	Y	pitching	M	$Z \longrightarrow X$	pitch	θ	v	q
Normal	Z	Z	yawing	N	$X \longrightarrow Y$	yaw	ψ	w	r

Absolute coefficients of moment

$$C_l=\frac{L}{qbS} \qquad C_m=\frac{M}{qcS} \qquad C_n=\frac{N}{qbS}$$

Angle of set of control surface (relative to neutral position), δ. (Indicate surface by proper subscript.)

4. PROPELLER SYMBOLS

D, Diameter.
p, Geometric pitch.
p/D, Pitch ratio.
V', Inflow velocity.
V_s, Slipstream velocity.
T, Thrust, absolute coefficient $C_T=\frac{T}{\rho n^2 D^4}$
Q, Torque, absolute coefficient $C_Q=\frac{Q}{\rho n^2 D^5}$

P, Power, absolute coefficient $C_P=\frac{P}{\rho n^3 D^5}$.
C_s, Speed power coefficient $=\sqrt[5]{\frac{\rho V^5}{P n^2}}$.
η, Efficiency.
n, Revolutions per second, r. p. s.
Φ, Effective helix angle $=\tan^{-1}\left(\frac{V}{2\pi rn}\right)$

5. NUMERICAL RELATIONS

1 hp = 76.04 kg/m/s = 550 lb./ft./sec.
1 kg/m/s = 0.01315 hp
1 mi./hr. = 0.44704 m/s
1 m/s = 2.23693 mi./hr.

1 lb. = 0.4535924277 kg
1 kg = 2.2046224 lb.
1 mi. = 1609.35 m = 5280 ft.
1 m = 3.2808333 ft.